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Art. XXV.—*General and Mining Geology of the Diamond Creek Area.*

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(With Plates XXV. and XXVI.).

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1.—Introduction.

The area discussed in this paper comprises the central and western portions of the Parish of Nillumbik. The author originally intended to map the eastern portion also, but owing to a rather late beginning and to concentration on the mining geology, this was not possible. Nevertheless a fair amount of field work was done in the neighbourhood of Kangaroo Grounds. The only previous mapping done in the area was a rapid survey of portion of the Parish of Nillumbik by O. A. L. Whitelaw in 1895, and the mapping of the main axial lines east of Diamond Creek by J. T. Jutson.

2.—Previous Literature.

1. A. R. Selwyn began the literature on this area in a report on the Geological Structure of the Colony of Victoria, the Basin of the Yarra, etc.; Votes and Proceedings of the Legislative Council of Victoria, 1855-1856, Vol. 2, Pt. I., with plans and sections.

In 1876, R. Brough Smyth[1] briefly described the general mining features of the Diamond Creek gold field. He mentions the occurrence of eurite at Diamond Creek, and draws a parallelism between it and the acid dykes at Mount Bischoff, Tasmania. He also traced a line of older basalt and gravels from Kangaroo Grounds past the Dandenongs to the River Latrobe, and thence to near the coast in South-West Gippsland. In 1894, R. A. F. Murray[2] visited the auriferous "cement" deposits near Greensborough, Eltham and Kangaroo Grounds, and reported very briefly thereon.

In 1895, O. A. L. Whitelaw, of the Victorian Geological Survey, made a rapid survey of portion of the goldfields between Warrandyte, Greensborough and Queenstown. He mentions a distinctive band of sandstone traced from the River Yarra to Diamond Creek, and intersected by spurs and veins of a dioritic dyke. He was of the opinion that the quartz reefs were formed along a line of anticlinal fracture.

H. S. Whitelaw[3] in 1899 noted the occurrence of stibnite in quartz reefs, and in certain bands of the silurian at Diamond Creek.

In 1900, V. R. Stirling[4] reported on the New Pioneer reef, Nillumbik. A ferruginous quartz-reef, two to four inches wide, and dipping at about 70 deg. to the west, had been worked with fair success.

1 R. B. Smyth. Report on Eltham and Allendale gold field. Prog. Report Vict. Geol. Surv., No. 3, 1876, pp. 34-38.

2 R. A. F. Murray. Report on the auriferous country near Queenstown. Prog. Report Vict. Geol. Surv., No. 8, 1894.

3 H. S. Whitelaw. Antimony ores in Victoria. Prog. Report Vict. Geol. Surv., No. 10, 1899.

4 V. R. Stirling. Notes on the New Pioneer reefs, Nillumbik. Monthly Prog. Report Vict. Geol. Surv., No. 10, pp. 7, 8, 1900.

Mr. Dunn,[1] in 1905, visited the Union Mine, Diamond Creek. In his report he mentioned the northerly pitch of the country and of the shoots of gold. He stated also that the quartz veins were filling contraction fissures in the dyke, and that payable gold would probably be localised near the intersection of the footwall reef with certain bands of the country rock. Two sections illustrating the relations of the dyke, breccia and quartz reefs with the silurian, accompany the report.

J. T. Jutson,[2] in a paper read before this Society in 1909, described very fully the physiographic characters of the Plenty River. The present valley of the Plenty, south from Morang, is described as a young stream which has eaten its way back towards the old Plenty River near Morang. A tongue of newer basalt filled up this valley to near Greensborough, and the present valley was carved out near the junction of the newer basalt with the older rocks.

J. T. Jutson,[3] in an excellent physiographic paper on the history of the Yarra River and Dandenong Creek basins, has described the Nillumbik peneplain, and he has shown that the Yarra River in its course through the Warrandyte gorge is a revived antecedent stream.

The age of the Nillumbik peneplain is discussed, and he shows that the age is probably kalimnan, and that uplift probably dates from late kalimnan, and has continued to very recent times.

In 1910 Jutson[4] described the interesting Warrandyte goldfield. The silurian sediments are described, and the main folds mapped. The probable age of the series is discussed, and he states that the oldest beds are probably at Warrandyte, and the youngest in the Bulleen syncline, and that the beds near the Diamond Creek are intermediate in age.

3.—Physiography.

The area is part of what has been called the Nillumbik peneplain.[5] The average elevation is between 300 and 400 feet, and the highest point is at Garden Hill, Kangaroo Grounds, which is

1 E. J. Dunn. The Union Mine, Diamond Creek. Rec. Vict. Geol. Surv., vol. ii., 1907-1908, pp. 33-35.

2 J. T. Jutson. A contribution to the physical history of the Plenty River, etc. Proc. Roy. Soc. Vict., vol. xxii., Pt. II., (n.s.). 1909.

3 J. T. Jutson. Physiog. of the Yarra river, etc. Proc. Roy. Soc. Vict., vol. xxiii., (n.s.), Pt. II., 1911.

4 J. T. Jutson. The structural and general geology of the Warrandyte gold field and adjacent country. Proc. Roy. Soc. Vict., vol. xxiii., Pt. II., 1911.

For purposes of reference we shall call these papers by Jutson, a, b, c, respectively.

5 Jutson. b, p. 477.

very nearly 1000 feet above sea level. The greater part of the peneplain consists of folded silurian sediments. Patches of basalt and gravel occur near Kangaroo Grounds and Greensborough. Residuals or monadnocks are few in number, and therefore presumably peneplanation was almost complete, and the then existing streams were probably all nearly base levelled. This being so, the present elevations of the river gravels should afford a clue in determining the variation in direction and intensity of the later movements connected with the uplift of the peneplain. The uplift was slow and differential in character, as is well shown by the antecedent character of the Yarra near Warrandyte. [1, 2] Tilting of the peneplain has occurred in an east and west direction, and also to a slight extent in a north and south direction. On going north towards Queenstown and Kinglake, the country is seen to rise gradually. The east and west slope, however, is very marked, a difference of over 400 feet in the elevation of the gravels occurring in a distance of about five miles. Thus, near Greensborough, the elevation of the gravels is about 350 feet.[3] About one mile east of the Diamond Creek mine, the elevation is 520 feet. At the west edge of the Kangaroo Grounds basalt, the elevation of the gravels is 650 feet, and near the cemetery about 750 feet. It is thus seen that as we go east across the area there is a progressive and moderately uniform increase in elevation. Following on the uplift a new cycle of stream activity was initiated, with the result that the peneplain has been rather deeply dissected, although at the same time dissection is far from being matured. The area is moderately hilly, numerous gullies and small streams abound, and the differences in elevation between these water courses and the hills are generally from 150 to 300 feet. The Plenty and Yarra Rivers have been described by Jutson, as has been above noted. The Diamond Creek, within the limits of the area, is in a fairly matured state. Fairly wide alluvial flats occur, and the creek meanders through these from side to side. The material constituting the flood plain is generally fine sand, and no coarse gravels occur, indicating that former stream velocities could only have been moderate. Residuals in the peneplain are few, and the main ones have been mentioned by Jutson. No physiographic evidence of faulting occurs in the area, although not far to the east, near Yarra Glen, such faulting has been described by Jutson.[5]

1 J. W. Gregory, Geography of Victoria, p. 106, 107.
2 Jutson. b, p. 485.
3 Note all elevations are aneroid readings.
4 b, p. 502.
5 b, p. 478.

4.—Stratigraphy.

The following formations are represented in the area:—

Palaeozoic	Silurian sediments.
	? Devonian acid dykes.
Tertiary	River or lacustrine gravels, sands, etc.
	Basalts.
Recent alluvium.	

The oldest member of the series consists of interbedded sandstones, mudstones and shales, containing considerable amounts of muscovite, and varying greatly in colour and coarseness. Occasional bands of quartzite and slate occur at intervals, and a series of grits and conglomerates has been described from Warrandyte.[1] From the various lithological and microscopical characters of these rocks they appear to be entirely marine, and to have been laid down mostly under shallow water conditions. Cf Jutson, c, p. 530. Some of the sandstones in the west of the area show good current bedding on a small scale, one section in particular from Dry Creek showed this very well. No extensive palaeontological work was attempted, mainly owing to lack of time. An interesting find, however, was the discovery of graptolites in black pyritic slates from the Diamond Creek mine. Dr. Hall has kindly examined these, and he has informed me that both climacograptus and diplograptus are represented, but he says there was not sufficient evidence to enable their precise age to be determined. It may be of interest to note that climacograptus and diplograptus both range into the lowest member of the silurian, namely, the llandovery series in England; but as fas as the writer is aware, neither have been definitely proved to exist in the silurian in Victoria. It seems clear, therefore, that the beds near Diamond Creek are at least melbournian or older in age, and probably older than Jutson was inclined to regard them. It might be noted in this connection that Selwyn regarded the beds of the Templestowe anticline, i.e., the anticline near Diamond Creek, as the oldest of the series. Two or three other fossils were found, and for the examination of them the writer is indebted to Mr. Chapman. The first fossil is from section 7, allotment 3, in the east of the area, and is a trachyderma, which Mr. Chapman informs me occurs both in melbournian and in the yeringian, and so is of no diagnostic value. The other fossil examined was from the Plenty River just below the aqueduct.

1 Jutson. c, p. 530.

Mr. Chapman describes it as the remains of a phyllocarid resembling *Dithyocaris praecox*, Chapman, but much smaller. A similar form has been found in the melbournian at Merri Creek.

Acid dykes.

Three of these, namely, the Dry Creek dyke, the Diamond Creek dyke, and the Warrandyte dyke occur in the area investigated, although only the former pair have been studied in detail. The Diamond Creek dyke is most important economically, as it is with this dyke that mining operations in late years have been mainly concerned. Their exact age is not stratigraphically determinate. They are later than the folding of the silurian, and are overlaid in some cases by alluvium. In one case, in section 16, allotment D, a basaltic dyke cuts across one of these dykes. The age of the basic dyke is probably about middle tertiary, and so it affords little value in the determination of the age of the acid ones. Probably the intrusion of the acid dykes was connected with the earth movements that caused the folding of the silurian, and these are probably devonian in age.

Sub-basaltic river gravels, sands, etc.

Lithologically all stages are present in these between coarse gravels with pebbles up to six inches in diameter, and fine unconsolidated sands. Frequently the sands and gravels have been cemented together forming the following:—

Silicified grits grading into quartzite. Ferruginous grits where the cementing material is either limonite or hematite. Calcareous grits, consisting of quartz grains, set in a paste of calcium carbonate.

Where the grains of quartz are more angular, various types of breccia are formed. Thin bands of limestone occur interbedded with the sands in several places. Silicification of the fine sands frequently occurs with the formation of quartzite. Professor Skeats and Mr. Summers[1] have noted the intimate association of the quartzites with the lava flows in the Macedon area. While this is frequently the case near the basalts at Greensborough and Kangaroo Grounds, quartzite does nevertheless occur associated with the sands and gravels, where no basalt is present. In such cases an origin such as that suggested by Prof. Gregory[2] might be

1 Professor Skeats and H. S. Summers, M.Sc. Bulletin Vict. Geol. Surv., No. 24, 1912.

2 J. W. Gregory. The geography of Victoria, p. 94.

likely. Near the margin of the basalt in several places, but especially near the northern limit at Greensborough, good examples of fossil wood have been found. The structure has been remarkably well preserved in some examples. A section of the wood was examined by Prof. Ewart. He informed me that he felt sure that the wood belonged to the eucalypts, but that one section was not sufficient to correlate it with existing species. The sands are frequently horizontally bedded, and some sections show good current bedding. The gravels which were formerly the position of the valleys now frequently occur as ridges elevated above the surroundings. The reason for this is twofold, (1) the basalt has protected the gravels, and even in places where the basalt is not now present, it may formerly have covered them, (2) the resistant character of the gravels in themselves. Small amounts of gold occur in the sands and gravels throughout the area, and they have been worked at several places with indifferent results. Just to the east of the main road from Greensborough to Diamond Creek, near the southern limit of the basalt, over £1000 worth of gold was won in about seventeen years. The sands were also extensively used in the construction of the Maroondah aqueduct.

Basalts.

The basalts occur in the extreme east and west of the area; one small patch occurs about one mile to the east of Diamond Creek. The writer has separated them on petrological grounds into 3 types.

1. Fine grained aphanitic basalt.
2. Medium to coarse grained basalt and dolerite.
3. Garden Hill basalt, medium to fine grained in character.

No field separation of these types was possible. The first type is well exemplified in a quarry off the main road near the northern limit of the basalt at Greensborough, and also in a quarry just to the south-east of Garden Hill. In both quarries the basalt is clearly the basal member, and has filled up the prebasaltic stream valleys. In both cases also columnar structure indicative of fairly rapid cooling has been developed. The columns are vertical and cleanly cut. The second type is a rather coarse grained basalt or dolerite.[1] It is the average type throughout the area, and it overlies the finer grained type near Greensborough and Kangaroo Grounds.

The third type, as the name suggests, is typically developed at Garden Hill, Kangaroo Grounds. It is medium to fine grained

1 Chamberlin and Salisbury. Processes and Results, p. 398.

in character, and is frequently vesicular. Further down the slopes of Garden Hill, the basalt is a dark compact fine grained type. No stratigraphic determination of the age of the basalts is possible, since they overlie leads whose age also is in doubt. The basalt at Greensborough is older than the newer basalt to the east of Melbourne, since a tongue of this basalt has filled up the old valley, which has been cut near the junction of the older basalt and gravels with the silurian. On petrological and physiographical grounds the writer has no hesitation in correlating it with the older rather than the newer basalt. The 1902 geological map of Victoria issued by the Geological Survey shows the Greensborough basalt as older basalt and the Kangaroo Grounds type as newer basalt. A later map published by the same department shows both as older basalt. More certain evidence of their age is obtainable physiographically. Jutson[1] mentions that the Kangaroo Grounds basalt is a monadnock in the peneplain. He[2] also has shown that the age of the peneplain is probably kalimnan, that is, lower pliocene[3] or upper miocene. This being so, the age of the basalt is prepliocene and probably miocene. The brief investigation of this point by the writer supports the view that the Kangaroo Grounds basalt is a monadnock, and that very little vertical erosion occurred between the filling up of the river valleys by the basalt, and the final peneplanation. At Greensborough the evidence is less certain, but petrologically these basalts appear to be identical, and the writer believes therefore that they were both extruded towards the end of the peneplanation, and therefore their age is probably miocene. The Garden Hill basalt occurring at the highest point of Kangaroo Grounds is much more scoriaceous, and has a smaller specific gravity than the main Kangaroo Grounds basalt, and is possibly of more recent age.

5.—Structural Features.

(a) *Folding, crumpled anticlines; zones of crushing.*

The silurian sediments have been normally and fairly openly folded throughout most of the area. The major axial lines in the east of the area have been mapped by Jutson. The positions of these have been verified by the author, and, in addition, a few minor folds have been located. A major fold is well seen in a railway cutting near Greensborough station, and the same fold has

1 b, p. 502.

2 b, p. 493.

3 F. Chapman. A study of th Batesford limestone. Proc. Roy Soc. Vict., vol. xxii. (n.s.), Pt. II.

been picked up where it crosses the Maroondah aqueduct in the north of the area. The railway section shows that near the axis the fold is extremely crumpled and crushed. Small thrust faults having displacements of three or four feet are common. No quartz reefs occur near by, and this is what we might expect. In general it is only in places where the rocks have fractured by tension as near the anticlinal axes that fissures have formed through which solutions have reached the surface. Following Gregory and Jutson it is proposed to call the above fold the Greensborough syncline. The western limb of this syncline consists of fairly steep, dipping beds, and near the Plenty River it passes into a sharp anticlinal flexure. The anticlinal axis is not symmetrical having a dip to the east of about 70 deg. In a section in Dry Creek an acid dyke occurs right on the axis. Going further east from here along the east and west bend of the Plenty River, two or three minor folds occur fairly close to one another. The Templestowe anticline is, however, the axis with which we are most directly concerned. Jutson[1] has traced this fold for nine miles south of the northern boundary of the parish of Nillumbik. The writer has traced it still further north to near Hurst's bridge, that is, for about three miles further north. The western limb of the fold, as Jutson has pointed out, is very greatly contorted and fractured. This is very well exemplified at and near the Diamond Creek mine. The silurian sediments throughout the area are well jointed, but near the above-mentioned anticline, rectangular jointing is sometimes so well developed that it is almost impossible to distinguish bedding from joint planes. This is well illustrated in cuttings in the recently-opened railway to Hurst's bridge. Another interesting feature are the numerous bedded and nearly vertical joint plane reefs in close proximity to the axial lines, especially the anticlines. It appears clear, therefore, that the pressure near the anticlinal axes during folding was tensional, and led to the formation of fractures and fissures through which mineral-bearing solutions have reached the surface, while the pressure in the synclines was compressional rather than tensional, as is shown by the ease of the Greensborough syncline above mentioned, and hence no passages or outlets for solutions from below occurred. Hence the reason for the localisation of the mining belts to the anticlines,[2] such as Warrandyte and Diamond Creek, is apparent.

Associated with the Diamond Creek dyke there occurs a zone of brecciation which will be dealt with in detail later.

1 Jutson. b, p. 522.

2 The proximity of acid dykes to the anticlines near Warrandyte, Diamond Creek, Dry Creek and Templestowe further illustrates this point.

(b) *Dip and strike of the silurian and evidence of pitch.*

The strike of the folded sediments is fairly constant throughout. The maximum value of the strike is about north 45 deg. east, and the minimum value is a few degrees west of north. The average value is about north 20 deg. east. It is only in the west and northern parts of the area that any considerable variation from the average value occurs. To the north-west of Greensborough, near the bend to the west of the Plenty River, the strike is nearly north and south. The dip varies considerably, and when away from the axial lines the average value is between 50 deg. and 60 deg. In the east and north-east of the area, Jutson[1] has shown that the beds have a decided northerly pitch. Certain sections along the aqueduct illustrate this very well. Near Diamond Creek and further west near Greensborough, however, no defined regional pitch occurs. Mr. Dunn[2] has stated that the pitch of the beds near Diamond Creek is to the north. The writer has not been able to verify this, and he believes that no regional pitch is here present, but that minor local pitches do not infrequently occur.

(c) *Relation of mining belts to structural features.*

Since the fine and instructive paper by Emmons[3] in 1886, it has become more and more recognised that the study of the structural features in any mining field is essential to the complete mastering of the various problems connected with the ore deposits. We have in Victoria, at Bendigo, perhaps as fine an example of this connection as we might wish for. It is essential, therefore, that we should study the structural features in some detail. This has been done to some extent above, and it has been seen that the payable quartz reefs in the silurian in this area, in practically all cases, are localised to near the axial lines, and generally to near the anticlines, and a reason for this has been suggested. Synclinal reefs do sometimes occur, however, as at Warrandyte,[4] and in a section along the railway line between Greensborough and Eltham, a minor anticline and syncline occur with a thin bedded synclinal reef. Jointing has been shown

1 Jutson, c, p. 525.
2 Op. cit.
3 S. F. Emmons. The structural features of ore deposits. Trans. Amer. Inst. Min. Eng., vol. xvi., p. 804-839.
4 Jutson, c, p. 535.

to be extensively developed near the Templestowe anticline. and the joints are seen to be mainly strike joints, and are probably connected with the folding of the sediments.

(d) *Faulting.*

Two main periods of faulting have been noted :—

1. Pre-mineralisation.
2. Post-mineralisation.

As examples of faulting previous to the formation of the quartz reefs, we have the brecciated zone, now occupied by the Diamond Creek dyke, and probably the slips parallel to the bedding planes belong to this period. Movement later than the formation of the reefs is well illustrated by the numerous strike faults occurring in the Union and Diamond Creek mines. This type of faulting has not been recognised elsewhere in the area, although it is possible, but not probable, that such faulting has been missed, due to the fault planes coinciding with the dip of the beds.

As regards igneous intrusions, the basalts and acid dykes have already been described under stratigraphy. Only two basic dykes[1] from the area are known to the writer. One was found by Howitt[2] at the Caledonia mine, Warrandyte, and was determined by Professor Skeats as a monchiquite, and the other was found by the writer in section 16, and is described later.

6.—Petrology.

(a) *Sandstones and their origin.*

Several sections of the sandstones from various parts of the area have been examined by the writer. Section A18 from the Watts River aqueduct near the Warrandyte anticline is a typical example.

In hand specimen it is seen to be a dark-coloured, dense, micaceous rock.

Microscopically the following minerals are recognisable :—Quartz, muscovite, chlorite, flint, tourmaline, zircon, rutile, apatite, magnetite, leucoxene, biotite, plagioclase, iron oxides and patches of carbonaceous material. Quartz occurs in all sections examined in well over 90 per cent. of the rock. The grains are either angular or subangular, and are very rarely rounded. Numerous micro-

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1 The writer has since seen in the National Museum, Melbourne, a specimen of *mica lamprophyre* from the Union Mine, Diamond Creek.

2 A. M. Howitt. Notes on a Sketch Survey of the Caledonia Reefs at Warrandyte. Rept. Geol. Surv. Vict., vol. 3, Pt. 1, 1909, p. 40.

scopic prisms of rutile or zircon, and linearly arranged gas and liquid inclusions are present in the quartz grains. Strain polarisation is a common feature in the quartz grains. Muscovite is fairly common, and occurs as twisted flakes which are frequently bordered by green chlorite. Chlorite also intrudes itself along cleavage planes. A brownish green variety of chlorite is more common, and it appears to be an alteration product of some iron magnesium mineral, as biotite. Biotite and an acid plagioclase also occur in small amounts in nearly all sections. Of the usual concentrates found in such rocks as these, zircon and tourmaline are most common. The detrital origin of these is evident by the rounding of the salient angles in the prismatic crystals. Rutile is not uncommon, and generally occurs in brown prismatic crystals. The individual quartz grains are generally not very closely packed, and the cementing material usually is micro- or cryptocrystalline silica, which is often stained with brown hydrated iron oxide. Occasionally fine sericitic mica and chloritic material form the bond. In the fossiliferous grit from Warrandyte, the cement is largely calcite. The nature of the rocks from which the silurian sediments were derived has been discussed by Jutson.[1] He showed that the pebbles in the Warrandyte conglomerate were practically entirely of a sedimentary nature, i.e., quartz, quartzite and sandstone, and no pebbles of an igneous rock were present, and this led him to conclude that the rocks from which the conglomerates were derived consisted largely, if not entirely, of altered and unaltered sediments. In such an old conglomerate as this, however, we might well expect to find only the more resistant rock types, like the ones above-mentioned, remaining, although igneous rocks may have originally been present. On petrological grounds, the writer draws the conclusion that the sandstones were derived to a fair extent at least from a pre-silurian igneous rock, probably granitic. This view is supported by the following evidence :—

(1) The abundance of muscovite ;

(2) The presence of biotite and plagioclase, and chlorite, which is usually derived from unstable iron magnesium minerals;

(3) The occurrence of zircon and rutile crystals in the quartz grains in the sandstone may indicate an igneous origin for such quartz.

(4) The constant presence of tourmaline supports such an origin;

(5) The absence of metamorphic minerals, garnet, etc., show that they were not derived from metamorphic rocks.

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1 c, p. 532.

(b) *Basalts.*

1. Fine grained basalt, quarry near the northern limit of the basalt at Greensborough. Macroscopically this rock is dark grey in colour, and is compact, and aphanitic with the exception of occasional felspar phenocrysts. A sample was collected from the quarry above mentioned and analysed by the writer in the University geological laboratory. The weathering of the basalt in this quarry has led to the solution of lime and magnesia, and these have been redeposited as a magnesian limestone. For the purpose of comparison an analysis by F. L. Stillwell of the older basalt from near Broadmeadows is appended.

	A.	B.
SiO_2	46.43	44.95
Al_2O_3	17.60	15.50
Fe_2O_3	8.51	2.04
FeO	2.44	10.47
MgO	8.03	7.43
CaO	8.12	8.24
K_2O	0.92	1.98
Na_2O	3.56	3.04
H_2O+	1.20	2.60
H_2O-	0.81	0.52
CO_2	p.n.d.	0.18
TiO_2	2.25	2.77
P_2O_5	0.37	0.52
MnO	0.22	0.21
(Ni,Co)O	0.07	—
Total	100.53	100.45

A. Fine grained basalt quarry off main road, near northern limit of the basalt, Greensborough—S.G. 2.94.

B. Older basalt (A) quarry, Section 15, Tullmarine, county of Bourke.

Microscopically the texture is aphanitic with occasional porphyritic felspars. The mineral composition of the rock is thus:—Plagioclase, olivine, augite, magnetite, ilmenite, zeolites and apatite. Plagioclase occurs in two generations, firstly as long idiomorphic clear and glassy laths showing lamellar twinning generally, but occasionally only simply twinned. Pressure effects, probably of a local origin, are noticed in the twisting and fracturing of the laths, by wedging of the twin lamellae, and also by cross fractures almost at right angles to one another, and generally oblique to the planes of twinning. Olivine is almost indeterminate in ordinary light, due to its invasion by the ground mass. Concentration of black iron oxide occurs frequently in the centre of the crystals, and radiating linearly arranged rods of the same material pass out to the edges. In bright, reflected sunlight, the olivine is seen to be mostly altered to red iron oxide, probably hematite. An occasional porphyritic crystal of augite occurs, and has suffered like the olivine. The bulk of the augite, however, occurs scattered through the ground mass of the rock as yellow and colourless anhedral grains and prisms. The ground mass of the rock consists of microscopic laths of felspar, often in fluidal arrangement, and abundant dust and fine grains of black iron oxide. Zeolites occur in all sections examined, and they are frequently associated with apatite needles, and contain prisms of augite and grains of magnetite as inclusions. The phenocrysts of olivine and plagioclase had probably crystallised out from the magma before extrusion, and rapid chilling caused the separation of microlites of felspar and dust of iron oxide. Section A32, Kangaroo Grounds, quarry, south-east of Garden Hill, shows pilotaxitic structure. Zeolites of very low birefringence occur filling vesicles. Radiating natrolite with birefringence, considerably above the felspar also occurs, filling steam cavities. Section A28 shows olivine frequently clear and colourless. Occasionally the outlines of felspar now replaced by zeolites are seen.

2. Medium to coarse grained basalt.—In hand specimen, with the aid of a lens, crystals of weathered olivine and felspar laths can be sometimes identified.

Microscopically this type differs from the first in the presence of numerous phenocrysts of titaniferous augite, and in the nature of the ground mass. Section A15, Kangaroo Grounds, is a holocrystalline fairly even grained hypidiomorphic rock with ophitic texture. The minerals present are plagioclase, augite, olivine, magnetite, ilmenite and apatite. Zeolites and chlorite occur as secondary constituents. Plagioclase is present in long prismatic laths, frequently zoned, and having a maximum extinction of about 42 deg. The augite is a titaniferous variety, and it is pleochroic from purple to brown or yellow, and occurs in anhedral forms. Extinction angle of the augite is 50 deg. from 100. The augite is ophitically penetrated by the felspar laths. Numerous inclusions of olivine occur in the augite. Olivine is present chiefly as allotriomorphic grains. Alteration has taken place along cracks to greenish chloritic material, and occasionally to red iron oxide. Magnetite commonly occurs idiomorphic as octahedra. Numerous irregular grains, purple in reflected light, are probably ilmenite. Low polarising zeolites frequently fill interstices in the rock. The rock may be described as an ophitic olivine dolerite.

Section A23, Kangaroo Grounds, near the cemetery. In this section the ophitic texture is absent, and the felspar laths are larger than in section A15.

3. Garden Hill basalt.—This type differs from the second type in the rarity of the phenocrysts of augite, and in its finer grained character. The specific gravity of this type is also markedly different from that of the former types. The specific gravity of the third type is about 2.86, while that of the first two types is about 2.93.

Section A24, south of Garden Hill, is a typical example. In hand specimen it is a black, dense, almost aphanitic rock.

Microscopically it is a holocrystalline fine grained rock, showing pilotaxitic structure, and having a tendency towards a porphyritic habit. Phenocrysts of olivine occur in a moderately fine grained base of augite, plagioclase, magnetite, ilmenite and apatite. Secondary minerals, as serpentine, zeolites and iddingsite are present. Olivine, colourless, is occasonally altered to green serpentine, and red brown iddingsite. Augite occurs very rarely as purple phenocrysts, and is generally present as microscopic anhedral grains and prisms, having an extinction angle about 45 deg. Long prisms of felspar, with maximum extinction angle about 33 deg., indicate labradorite of composition near Ab_2 An_3. Microspherulitic zeolites occur distributed throughout the ground mass.

Section A21, Garden Hill.—Olivine is largely replaced by iddingsite. Small amount of glass or isotropic zeolite present.

(c) *Dykes.*

1. Basic dyke. This dyke occurs in a small shaft in section 16, allotment D. It was not possible to determine its strike or to trace it on the surface. Macroscopically it is a greenish grey coloured amygdaloidal rock, resembling a basalt. It weathers to a brown iron-stained material containing numerous unaltered crystals of augite. Microscopically it is a holocrystalline, panidiomorphic, porphyritic textured rock. It consists mineralogically of phenocrysts of olivine and augite in a ground mass of microlites of felspar, granular augite, olivine, magnetite and apatite. Secondary minerals comprise zeolites, talc, calcite and leucoxene. Augite occurs in large idiomorphic phenocrysts, brown or purple in colour, and decidedly pleochroic, indicating a titaniferous variety. Simple twinning on 100 is seen by re-entrant angles and differences in polarisation colours. Multiple twinning, twin and

composition plane 001 well developed. Iddings[1] mentions that this type of twinning is often developed by pressure. Extinction angle of the augite varies from 30 deg. to 37 deg. Cleavage parallel to 110 perfect. This augite is of interest since in some cases it appears to be almost uniaxial, and the writer was able to determine its sign as positive by the mica plate. A. N. Winchell[2] has noted that in a titaniferous pyroxene from Pigeon Point, Minnesota, the optical axial angle is so small that in some cases the mineral appears uniaxial. This seems to be the case in the above-mentioned augite. Inclusions of plagioclase in augite show that, in part, the augite crystallised out later than the felspar. Augite in the ground mass occurs as eight-sided granules and prisms. The prisms occasionally cross one another, forming stellate aggregates suggestive of the rare mode of twinning on ($\bar{1}22$).[3] Olivine occurs as anhedral crystals of moderate size, now almost entirely replaced by a colourless micaceous mineral with high birefringence, probably talc. Along cracks alteration to green serpentine or chlorite has occurred. Plagioclase is present in long laths, having a maximum extinction of about 37 deg. The rock may be described as a basaltic dyke.

2. Dry Creek dyke. Section A25, Dry Creek dyke, near the Plenty River. In hand specimen this is a light-coloured rock, frequently iron stained due to oxidation of crystals of pyrite. The minerals present are not determinable in hand specimen. Microscopically the texture is holocrystalline and porphyritic. Mineralogically the rock consists of phenocrysts of orthoclase and quartz in a ground mass of quartz, sericite, bleached biotite, plagioclase, orthoclase, magnetite and kaolin. Brown hydrated iron oxide is fairly abundant. Orthoclase is the chief porphyritic constituent. It is present as large, simply twinned crystals, having a maximum extinction angle of about 17 deg. Considerable replacement by quartz and sericite has occurred in many cases. Kaolin is probably a surface alteration of the orthoclase. Plagioclase having a maximum extinction angle of 14 deg. from the traces of the twin planes, to probably albite, occurs in considerable amount in the ground mass of the rock. The biotite has been bleached, and hydrated iron oxide has been redeposited along cleavage traces, and it is frequently associated with brown prisms of rutile. The considerable amount of iron oxide throughout the section represents the

1 Iddings. Rock Numerals, p. 305.
2 A. N. Winchell. Notes on a titaniferous pyroxene. Amer. Geologist, vol. xxxi., 1903.
3 Iddings. Op. cit., p. 305.

replacement of pyrites by limonite. An occasional six-sided crystal of quartz, partially replaced by sericite, is present. The original rock is thus seen to have been a quartz felspar porphyry. A similar conclusion was reached as to the original character of the Diamond Creek dyke.

Section A21, from near the edge of the Dry Creek dyke, contains numerous xenoliths of sandstone and slate. The plagioclase is zoned, and the quartz is frequently eaten into and replaced by sericite.

3. Diamond Creek dyke.—This dyke was sectioned and examined before the writer had seen the Dry Creek dyke, and the main conclusions regarding the nature of the alteration it has suffered were thus deduced previous to the examination of the latter dyke. In hand specimen the Diamond Creek dyke is yellow green in colour, and contains abundant minute cubes of pyrite. Microscopically it is a hypocrystalline, very even grained aphanitic rock, with skeleton outlines of original porphyritic constituents. Microcrystalline quartz grains and flakes of sericite constitute considerably over 90 per cent. of the rock, the other minerals present being pyrite, stibnite, bleached biotite, rutile, carbonate occasionally, and possibly arsenopyrite and zircon. Idiomorphic outlines of the original felspar crystals are distinguished by the more compact nature of the sericite in such areas. The metasomatic replacement of the felspar is generally complete, and so the stages in the alteration are not determinable. In only one section of the Diamond Creek dyke did the writer see original orthoclase remaining. Rarely a residual phenocryst of quartz occurs. Sericite usually occurs in clear, colourless microscopic flakes, showing the usual delicate polarisation colours. Where replacing felspar, a linear arrangement of the sericite is sometimes seen. The original femic constituent of the rock was apparently biotite. As a result of the alteration, the biotite was leached, and simultaneously rutile separated out in the biotite areas. This separation was usually in the form of "segenite"[1] webs, but occasionally rutile occurs in prisms roughly parallel to the length of the biotite. Carbonate often occurs associated with quartz in veins through the dyke, but otherwise it is rare. Some of this vein carbonate was examined and found to be dolomite. Pyrite is common in cubic crystals, and stibnite is always present, but generally in very small amount when not near the quartz veins.

1 Rosenbusch, Iddings, p. 146.

(d) *Discussion of the alteration of the dykes.*

It will be seen that the Diamond Creek dyke consists of a very much altered porphyry. The alteration has been complete, and all of the original minerals have been replaced, and the ground mass has been recrystallised. Petrologically, it is seen that the biotite was the first mineral to be attacked, as in all sections of the Dry Creek dyke examined biotite was always entirely replaced, although plagioclase and orthoclase were sometimes only partially altered. The alteration appears to start first in the areas of orthoclase, although orthoclase occasionally remains when all the plagioclase has been replaced. Kirk,[1] in discussing somewhat similar mineral changes to those here described, has shown that the iron magnesium minerals are the first attacked, and that plagioclase commences to be replaced by sericite and quartz before the orthoclase is attacked. Replacement of the felspar frequently starts along planes of weakness, such as cracks and cleavage planes. An analysis of the Diamond Creek dyke was made for the purpose of studying the chemical migrations during the alteration. The analysis gave the following results :—

	A.
SiO_2	76.25
Al_2O_3	15.12
Fe_2O_3	1.86
FeO	tr.
MgO	0.18
CaO	tr.
K_2O	3.10
Na_2O	1.37
H_2O –	0.10
H_2O +	1.61
TiO_2*	—
S	0.92
MnO	tr.
Sb_2S_3	p.n.d.
	100.51
less O = S	.34
	100.17

A. Diamond Creek Dyke, 800 feet level, about 200 feet from the underlay shaft along the north drive, Diamond Creek Mine. S.G = 2.72.

—N. R. Junner, Analyst.

1 C. T. Kirk. Conditions of mineralisation in the copper veins at Butte Montana. Economic Geology, vol. ii., No. 1., 1912.

* TiO_2 included with the Al_2O_3

From the fair amount of biotite and lime soda felspars probably originally present, it may be inferred that the percentages of lime and magnesia were very much higher than in the altered rock. The iron has probably not changed very much in amount, but sulphur has been introduced either as sulphuretted hydrogen or as alkaline sulphides, and this has united with the iron forming pyrites. It is not possible to say from the evidence of a single analysis what migration has taken place in the alkalies, although it seems probable that a reduction in amount of both potash and soda has occurred. Silica and water have both apparently increased in amount. Sericite is essentially a potash mica, and in the analysis over one per cent. of soda is represented. This may possibly be due to the presence of the soda mica paragonite, although microscopically no distinction could be made out. Regarding the temperature of the altering solutions, Kirk[1] states "that where sericite can be certainly identified, it becomes a useful corroborative criterion in the interpretation of previous hydrothermal high pressure conditions." Rutile is also mentioned as forming under considerable pressure and moderate temperatures. We may, therefore, conclude that the alteration which the Diamond Creek dyke has suffered was probably of the nature of a solfataric after-effect under moderately high pressure and temperature operating on the quartz felspar porphyry. This type of alteration agrees with "propylitisation" as defined by Vogt.[2] Kirk[3] has summed up in tabular form the various alterations during propylitisation of the Butte granite, and the table below is a partial extraction.

Chemical Alterations.

Iron gained, sulphur added to form pyrite. Losses in lime, magnesia and soda; transformation of iron oxides to sulphides; decrease in all bases except potash. Gains in iron sulphide, silica and water, alumina, potash, etc.

Mineral Alterations.

Development of sericite, quartz, pyrite, chlorite, epidote, rutile, etc. Femic minerals are first altered and felspars are more resistant.

1 Kirk. Op. cit., p. 57.

2 Vogt. Genesis of ore deposits. Trans. Amer. Inst. Min. Eng., 1901, p. 668.

3 Op. cit., p. 67.

Physical Alterations.

Increase in density.

With a view to determining the change in density due to the alteration, the specific gravities of the Dry Creek and Diamond Creek dykes were compared, with the following result :—Density of little altered dyke at Dry Creek, equals 2.59. Density of the Diamond Creek dyke from the 800 feet level of the mine, equals 2.72. We see thus that a marked increase in specific gravity has occurred, and this is largely explained by the presence of pyrite in the one and its absence in the other. The chemical and mineral changes agree very well with those tabulated above, and the writer feels quite justified in calling the alteration a "propylitic" one. In the typical propylitic alteration, chlorite is generally developed, and the potash percentage is generally increased. The alteration of the above dykes appears to differ from the typical propylitisation in these respects. The only previous cases of propylitisation that have been described in Victoria are the Woods' Point dykes,[1] and a propylitised dacite[2] from Macedon. The Diamond Creek example differs from both of these in the absence of chlorite, and also in the fact that the ground mass recrystallised in eutectic proportions in both of the above cases, while it has not done so in the Diamond Creek dyke.

(e) *Dyke veins and slate reefs.*

Section A23.—Gold-bearing quartz vein in the dyke, Diamond Creek mine.

The vein is small, but very rich. The gold is seen without the aid of a lens sticking out at points through the vein. A considerable amount of stibnite is present, giving the quartz a dark colour. Under the microscope the gangue is seen to be practically entirely quartz, and the metallic minerals are chiefly stibnite and gold. Grains of a translucent, highly refracting and apparently isotropic mineral associated with the stibnite appear to be the oxide senarmontite. The section shows that the gold occurs in anhedral grains and masses, frequently disseminated through the stibnite, and occasionally intergrown with it. The intimate association of the gold and the stibnite is well recognised by the miners, for they say that wherever you find stibnite, gold is certain to be present. Lincoln[3] has examined twenty-eight specimens of gold stibnite veins

1 Prof. Gregory. Mem. Geol. Surv. Vict., No. 3, 1905, p. 34.

2 Prof. Skeats and H. S. Summers, M.Sc. Bull. No. 24, Geol. Surv. Vict., 1912.

3 F. C. Lincoln. Certain natural associations of gold. Economic Geology, vol. vi., 1911, p. 287.

from various localities, and he has shown that in 16 cases the gold occurs with the stibnite, in 7 cases disseminated through it, and in 4 cases intergrown with it. The above-mentioned section shows well the contemporaneous origin of the gold, quartz and stibnite. Pyrite occasionally occurs in the quartz veins associated with the gold, and in the 800 feet level small crystals of sphalerite were present.

Section A4, slate vein, 600 feet level south, Diamond Creek mine.

Quartz, sericite, carbonate, pyrite and stibnite are the minerals present. A series of roughly parallel wave-like fractures pass through the grains of quartz, and sericite and carbonate have intruded along these planes and replaced some of the quartz. Marked granulitisation of the quartz grains occurs. Pyrite and a little stibnite are present along cracks and through the vein.

7.—Geology of the Diamond Creek Mine.

The Diamond Creek mine is situated on a hill just to the east of the Diamond Creek, and just south of the railway station of the same name. At present it is the only mine working in the field, although the "Allendale" Company is about to recommence operations. Of late the working of the mine has been carried on with very fair results. For the half-year ending July 19th, 1912, 2009 tons of ore were crushed, yielding 2835 ounces of gold, giving an average yield per ton of 28.2 pennyweights. Five sixpenny dividends have been paid since the beginning of the year, and during the same time the shaft has been sunk a further one hundred and fifty feet. The main shaft is sunk vertically for 700 feet, and then on the underlay of the dyke for a further 280 feet. Most of the development work, especially in the lower levels, has been done north of the shaft. The reefs in the bottom levels were of very fair value, and there seems no reason why permanence in depth of the gold bearing veins should not be realised.

(a) *Features of the silurian, structural and lithological.*

The chief structural features of the silurian have been dealt with before. Near the mine the silurian consists of shales and sandstones and rarely small bands of black slate. These, when they occur in proximity to the dyke, are frequently changed to graphitic slate. Bands and small lenticular segregations of carbonaceous matter occur in nearly all the shales. The dip near the mine is to the W.N.W. at about 45 deg.—60 deg., and the strike is approximately N. 24 deg. E.

The dyke outcrops on the surface just to the west of the mine, and some good sections showing the various relations of the dyke breccia and silurian are seen in shallow workings in the dyke.

(b) *The breccia and crush conglomerate.*

This interesting feature was first examined in numerous workings along the line of the dyke below the mine, and north of the Diamond Creek. Numerous pebbles, set in a very fine matrix, frequently occur in the silurian alongside the dyke. At first sight this might be mistaken for a sedimentary conglomerate, but a little consideration shows that it is a fault conglomerate, and not a sedimentary one. In the first place all the pebbles consist of similar sandstone, shale and quartzite to the adjacent wall rock. Secondly, on the surface this conglomerate has been seen alongside the dyke at places over half a mile apart. Now the strike of the dyke is approximately north and south, while that of the silurian is about north 20 deg. east. Hence it will be seen that the conglomerate is not bedded, and cannot therefore be a clastic conglomerate. Thirdly, when examined in the mine, sections frequently show the junction of the normally dipping silurian with the breccia and dyke, and it is seen that brecciation occurs in a zone roughly parallel to the walls of the dyke. Also in some cases a passage from a breccia into a breccia conglomerate and crush conglomerate is noticeable. Fourthly, the cobbles show certain peculiarities, such as dimpling, plane surfaces where the cobbles have rubbed against one another flattening and twisting. The fault origin appears therefore to be clearly established. Considerable variation in the size of the cobbles has been noted. The average size is two or three inches in diameter, while one extreme example was over two feet long, and more than fourteen inches in diameter. When the fragments are angular and sub-angular the rock is called a crush breccia. Further rolling and crushing of the pebbles rounds off the angles and forms a crush conglomerate. Mr. Dunn[1] mentions the occurrence of the breccia on only one wall of the dyke. The writer, however, has seen that at the mine and elsewhere the breccia frequently occurs on both walls. This fault zone has acted as a plane of weakness, through which the dyke has been intruded. Horses of brecciated-material and fault cobbles are frequently found well within the dyke; in one case in the 300 feet level fault cobbles were seen as much as six feet within it. The dyke occasionally wanders from the zone

1 E. J. Dunn. Op. cit.

of brecciation, as is well seen in a section between the mine and the Diamond Creek station. The dyke in this section is seen to be bounded by crumpled slates, and the brecciated zone occurs seven or eight feet to the west. The width of the original fracture zone is probably not represented by the width of the dyke. Lateral pressure exerted during intrusion and a certain amount of stoping has probably enlarged the width of the fracture. It is not clear what the final displacement is, but it is probable that the movement was oscillatory, and the final displacement may have been small. If the quartz reefs on either side of the dyke at the surface are identical no great displacement can have occurred.

(c) *The Diamond Creek dyke.*

The dyke near the mine strikes practically north and south, and dips to the east at about 45 deg., i.e., the dip is approximately at right angles to the dip of the shales. In some places the dip is nearly vertical and in others it is much flatter than the average. Considerable variation occurs in the width of the dyke, both along its length, and in vertical sections. The maximium width is about 35 feet, and the average about 20 feet. Rectangular jointing, with one set of joints roughly parallel to the dip of the dyke, and the other set almost at right angles to these, frequently occurs. Slickensides, striae, brecciation and other evidence of movement under pressure are not uncommon, especially near the faults. Large horizontal slickensides occur in the dyke below the 300 feet level north, and large curved ones are not infrequently present in other parts of the mine. Impregnation with pyrites of the breccia and slates surrounding the dyke for a few feet has taken place.

(d) *Faulting later than the intrusion of the dyke.*

The best opportunity for studying this faulting was afforded at the mine. Nearly all these faults appear to be normal strike faults having a strike approximately north 20 deg. east, and hading to the west. Their strike varies from north 10 deg. east to about north 30 deg. east, and their hade is generally between the limits 40 deg. and 80 deg. The effect of the difference in strike of the faults and the dyke gives the faults the appearance of pitching to the north. Being normal faults, the dyke is always brought back in a westerly direction, and this has materially aided the company in the lower levels, where the dyke was going away from the shaft. In the Union mine, immediately to the south of the Diamond

Creek Company's workings, two fair-sized faults of this nature were encountered. The first one was passed through near the surface, and it intersects the dyke near the Diamond Creek shaft at the 500 feet level. The other one came in near the Union shaft at the No. 6 level. The vertical displacement, or blank ground, in this case was about sixty feet, and as yet it has not cut the Diamond Creek workings. Another fairly large fault of a similar nature has intersected the dyke near the latter shaft at about 200 feet from the surface. Numerous others, with displacements of 20 feet and under, occur throughout the mine. Considerable brecciation of the dyke has occurred near the faults, and later solutions passing through these fissures have deposited pyrites, and this frequently binds the fragments of dyke together. Besides these strike faults, one or two cross or "transverse" faults have been noted. A good example of this faulting occurs in the 700 feet level, south drive. The strike of the fault is about 15 deg. north of east, and it hades to the N.N.W.

8.—Relations of the various Quartz Reefs to one another.

(a) *Occurrence and relative size.*

At least 4 distinct types of veins have been observed. They are, in order of age as far as has been determined :—

1. Vertical reefs—oldest.
2. Bedded reefs.
3. Dyke reefs.
4. Joint plane reefs—youngest.

As an illustration of the first type, we have the reef which runs into the dyke from the south-west side of the main drive north, at the 300 feet level. The actual junction of the dyke with the slate reef was not seen, but sections along the drive show that the reef is not continuous across the dyke. The management have driven along the hanging wall of the dyke for some short distance with the view of locating the northern continuation of the reef. They were not successful, however, and it is probable that pre-dyke faulting connected with the brecciation has displaced the reef. On the surface two reefs, one of which is possibly the upward extension of the above mentioned reef outcrop on the north-east side of the dyke. From surface shafts which are only down to relatively shallow depths, and are nearly all vertical, it was not possible to be certain that these reefs were not bedded, as the dip of the silurian near by is very steep, being 70 deg. or 80 deg. The possibility of these reefs being bedded is not very likely, however, as the bedded reefs are generally very thin and barren, while these are much wider, and they are fairly rich. The reef at the 300 feet level dips slightly to the east, and cuts across west dipping country. This reef has been located about 500 feet south from where it junctions with the dyke, and its departure is about seventy feet from the dyke at this point. A reef worked for a short distance on the surface to the south-west of the dyke appears to be the upward continuation of this reef. Similar reefs occur in the Union No. 7 level, and in the Diamond Creek 400 feet level. In the Union level above-mentioned, the relation of these reefs to the bedded ones is well seen. The bedded reefs are seen to displace these nearly vertical ones, although the displacement is small, generally a foot or two. Jutson[1] has shown that the bedded reefs displace the main reefs in the Warrandyte goldfield. The reefs worked on the western limb of the Templestowe anticline, about three-quarters of a mile south of the Diamond Creek mine, are also probably of the same nature as those near the mine. The strike of the reefs in both cases conforms with the strike of the silurian, being north 15 deg. east to north 25 deg. east. Another reef of this kind was seen in a section in the Maroondah aqueduct just to the west of the Bulleen syncline. The reef is about 16 inches in width, and it has been displaced by a small dip fault. As far as the writer could learn, considerable amounts of gold have been won from these reefs. Near the surface they averaged about one ounce to the ton, and occasionally patches giving returns of as much as twelve ounces to the ton were found.

Bedded veins.—These are common at and near the Diamond Creek mine. They have been shown before to occur only in close proximity to the axial lines, especially the Templestowe anticline. The veins are generally thin. varying from ½ inch to 2 inches in casts of friction striae are well preserved in the quartz. In some places the quartz reefs give place to a small fissure filled with gouge or flucan. The relation of these veins to the dyke is rather obscure. Nowhere do they cut across the dyke. although occasionally the reefs have been traced on either side of it. These reefs, as far as the writer is aware, contain little or no gold, and their effect, if any, on the localisation of the gold in the dyke veins, is not apparent. The striae on the quartz show that the movement that has occurred was mainly a slip in the direction of the dip of the dyke.

1 c, p. 536.

Dyke Veins.—These are the most persistent and by far the most important economically of the reefs near Diamond Creek. Generally two well-defined reefs occur :—

1. Hanging wall reef.
2. Footwall reef.

Besides these, others are occasionally present, and sometimes one reef will split into two, and the parts may junction again to form the main reef. In general these reefs are approximately parallel to the walls of the dyke, and it is only on rare occasions that a quartz-reef cuts the dyke transversely. The reefs are generally within the dyke, sometimes as much as six feet, but generally only about twelve inches. An inch or so of pug sometimes accompanies these reefs and striae and slickensides are often present. The thickness of the reefs varies considerably, from a mere thread to two or three feet. The reefs, when they occur at the junction of the dyke and the shales, are usually smaller than the average, and sometimes they split up into a number of leaders, running out into the country.

Joint Plane Reefs.—These are not of any economic importance. They occur typically in the 600 feet level south. Here one section shows one of these reefs displacing a tongue of the dyke. and therefore they are later in age than the dyke.

(b) *Fissures and their origins.*

1. The dyke fissures. The frequent association of the dyke veins with a little flucan, and the striae on the dyke walls between the dyke and the quartz are suggestive of movement. The direction of the striae is generally, but not always. in that of the dip of the dyke, and having no north or south component. One very good example of these striae occurred on the footwall of the dyke in the stopes above the 800 feet level. where the quartz had been broken out. Two sets of striae were present, the first consisting of coarse corrugations. having no meridional component, and the second set were later, and very fine, and pitched to the south. The question is whether these movements occurred before the formation of the reefs or after. Rarely the striae are also on the quartz, indicating that the movement in part at least was later than the formation of the reefs. The writer believes that the reefs are filling contraction joints which are roughly parallel to the walls of the dyke, and that movement has occurred both before the formation of the reefs and for a while, after the ore had formed. According to this view the fissures are essentially neither contraction fissures nor fissures of

discission, but they are a combination of both. It is also fairly certain that the fissures in some places have been enlarged by metasomatic replacement. Absence of crustification, the dense character of the quartz, and irregular inclusions of dyke material, probably undigested portions, suggest this.

(2) Fissures in which the bedded reefs occur. The origin of these has previously been suggested as due to movements connected with the folding of the sediments. The correspondence of these reefs in dip and strike with the silurian also supports such an origin. Movement on a minor scale has taken place along the bedding before the formation of these reefs as noted above. Occasionally slipping has occurred along the bedding, although no reefs are present.

9.—Origin of the Gold Bearing Solutions.

One or two points bearing on this discussion might be first noted :—

(1) The close association of the quartz veins with the dyke suggests strongly some genetic relationship between them.

(2) The nature of the minerals formed in the dyke due to the alteration. These minerals have been shown above to be those that are formed by juvenile solutions rather than by vadose ones. Pyrite, for instance, is generally decomposed by the vadose waters, but is frequently formed by either upward or downward moving thermal waters.

(3) Assays of the pyrites and of the dyke have been made at various times to see whether it would pay to treat the proposition as a low grade one. Very little gold was found to occur in the pyrites, and still less in the dyke. It might be suggested that the gold originally occurred disseminated through the dyke, and that it was transferred to the veins by a process of lateral secretion. The assays show, however, very little gold in the dyke away from the mineral veins, and such a transference as suggested above does not seem likely to have occurred. The presence of stibnite in both the dyke and in the quartz veins suggests that the solutions which caused the alteration of the dyke, and those which introduced the gold were of similar origin. The fact that the Dry Creek dyke, which has been very little altered, contains very little gold,[1] is strong evidence in support of the view that the solutions which brought the gold into its present position were a final phase of the same solutions that caused the alteration of the dyke. The writer pic-

1 Cf. Gregory. Memoir Geol. Surv. Vict., No. 3, 1905, p. 34.

tures the following sequence:—The quartz porphyry was intruded from some magma, probably at considerable distance below the then surface, along a plane of weakness, namely, the zone of brecciation. After solidification, and probably while the dyke was still hot, alkaline sulphide solutions were introduced along fissures in the dyke, and these caused the extensive propylitisation. Finally, the gold stibnite and quartz were introduced through the same or enlarged fissures. Contrasted with the above alteration, is the effect of the present day vadose circulation. Pyrites is dissolved from the dyke, and from the brecciated fault zones, and becomes oxidised, and is redeposited in the lower levels of the mine as hydrated iron oxide. In abandoned and little-used workings, as in the Union mine, long needles and hair-like crystals of epsomite are abundant. Green vitriol ($Fe\ SO_4 . 7\ H_2O$), also frequently occurs, due to the oxidation of the pyrites. Where water has percolated down the hanging wall of the dyke, considerable alteration of the dyke to a clayey material, largely kaolin, has occurred.

10.—Additional Features.

Localisation of values, evidence of secondary enrichment, etc.

Owing to the rather limited study of the occurrence of the gold, the writer being largely concerned with the then working levels, namely, the two bottom ones and the uppermost one, sufficient data were not gained for the fixing of pay shoots of gold, although there is little doubt that they do exist. According to evidence that the writer has gained from the officials at the mine, there appear to be two main shoots.

1. North hanging wall or whin shoot.
2. South footwall shoot.

Of these two shoots, the northern one is the richer, and is more well defined than the southern one. They both pitch to the north, the north one at a very steep angle, and the south one at about 45 deg., so that they incline towards one another, and in the 700 feet level the two shoots are only 70 feet apart. The length of the shoots appears to be fairly uniform, and about 250 feet. With respect to the cause of the shoots, the evidence is largely of a negative character. Mr. Dunn,[1] in his examination of the Union mine, was inclined to think that the shoots were due to the selective influence of certain bands of the country rock. Appearances at the mine point against this, however. The best values occur when

1 Dunn. Op. cit.

the reefs are within the dyke. When the reefs wander out into the slate or breccia, no noticeable increase in values occurs, and, in fact, in such cases there seems to be rather a decrease in values.

The effect of the "diagonal"[1] veins. Bedded reefs are common at the mine, but their effect, if any, on the gold values is not clear. A very interesting case of local enrichment occurs in the 300 feet level north near the intersection of the dyke, with the nearly vertical shale reef before mentioned. Here a very rich pocket of gold occurred in the very fractured dyke. This fracturing in parts appears to antedate the formation of the quartz veins, as no definite reefs exist here, the dyke being simply veined by numerous very rich stringers of quartz. Three possibilities exist for the localisation of the gold at this point:—

1. Action of the shale reef.
2. Effect of pre-existing fractures.
3. Secondary enrichment.

The first effect may probably be omitted, for the same reason that the effect of certain bands of the country is out of question.

A section was made of the ore from here, and it was seen that the gold and stibnite were intimately associated, although both were secondary in relation to the quartz. The stibnite was seen to consist of aggregates of needles, and not to be like the usual secondary sulphides that occur in some mineral fields, such as Broken Hill, near the water level. Very little information could be gained regarding the character and value of the ore above the 300 feet level at the mine, as this was worked in the early days of the field. No great variation in values, as far as could be learned, occurred in going down from the surface. The evidence appears insufficient to justify us drawing any extensive conclusions with regard to secondary enrichment. The presence of senarmontite in the lower levels does not necessarily mean that the zone of oxidation reached that depth, but probably that such ore was near fractures down which surface waters percolated. The evidence, such as it is, tends to support the view that secondary enrichment has occurred to a limited extent. The great amount of strata removed since folding[2] would tend to concentrate the gold, while the dense character and small size of the quartz reefs would exclude any large circulation of solutions. In the neighbourhood of faults, enrichment has occasionally been noted. In the Union mine, the gold-bearing stone was mainly the footwall stone,[3] and the hanging wall stone was hardly

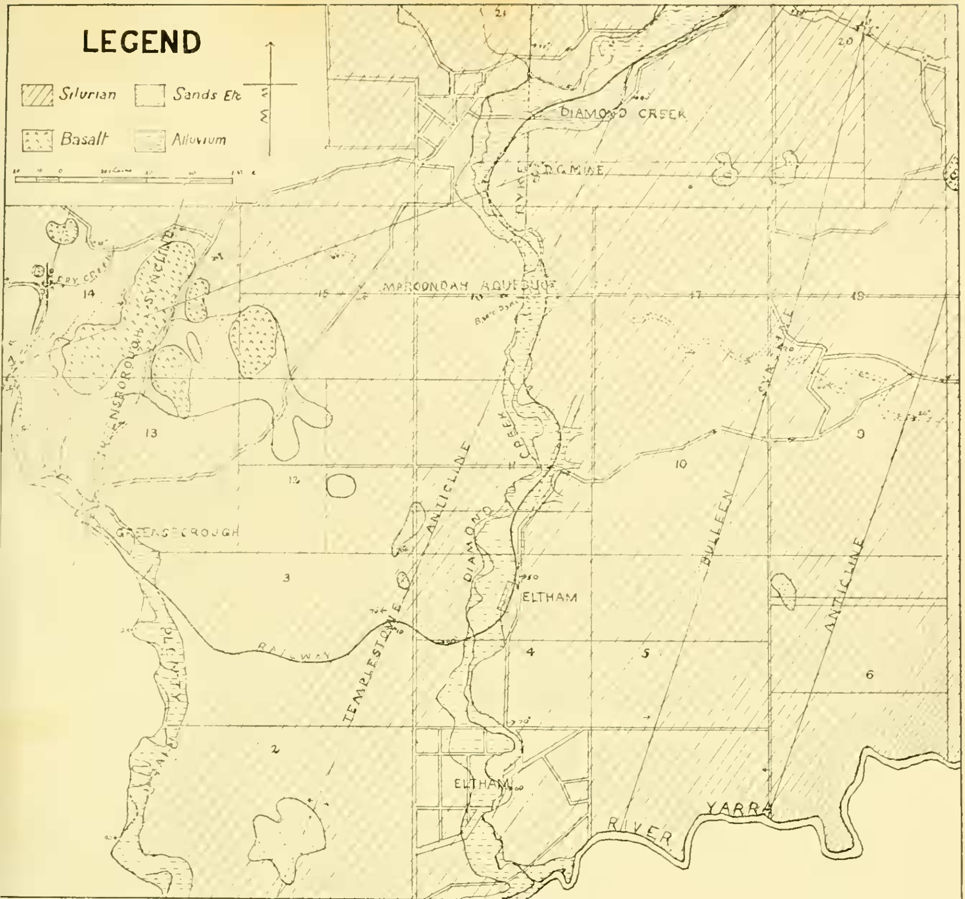
1 "Diagonal" is the miner's term for the slate veins.
2 Jutson. c, p. 550.
3 Dunn. Op. cit.

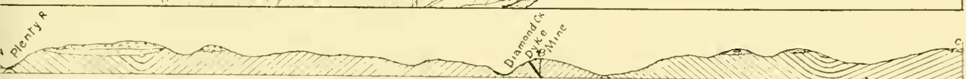
thought profitable to break out. In the south workings of the Diamond Creek mine, the footwall stone was worked almost exclusively. North of the shaft, however, both walls have been worked considerably. It is taken as a general rule at the mine that if the gold occurs on one wall it will not occur on the other. An exception to this was noted in the 700 feet level north, where the gold occurred on both walls.

Summary and Conclusions.

The study of the Diamond Creek area has brought to light some very interesting relations. The bearing of the present elevation of the river gravels formed before uplift in the direction of the slope of the peneplain has been noted. The stratigraphical relations have been described, and a few fossils found. The discovery of climacographtus and diplograptus in the so-called silurian near Diamond Creek is of interest, and should act as an incentive to further palaeontological work. The other fossils support a melbournian age for these beds. An intimate relation between the mining belts and the structural features, especially the anticlines, has been shown to exist. The petrological examination of two dykes from the area brought out some interesting relations; the Diamond Creek dyke appears to be an almost completely altered facies of a rock allied to the Dry Creek dyke. The former dyke has been described as a propylitised quartz felspar porphyry. The contemporaneous character of the gold and stibnite, and sometimes of the quartz, has been noted. Another interesting feature is the friction breccia and conglomerate, through which the Diamond Creek dyke has been intruded. The relations of the various quartz reefs, the problem of the genesis of the ores, the localisation and cause of the ore shoots, etc., have also been dealt with. Chemical analyses were made of the basalt and of the Diamond Creek dyke.

In conclusion, the writer wishes to record his indebtedness to Professor Skeats for his advice and suggestions on many occasions, and for his kind criticism of the paper; also to Mr. Summers, M.Sc., for help in the laboratory, and references to the literature. He also desires to thank Dr. Hall, Prof. Ewart and Mr. F. Chapman, A.L.S., for their kind examination of fossils, and Mr. Grayson for rock sections, and micro-photographs. To Mr. Christian, the manager of the Diamond Creek mine, the writer is greatly indebted for securing him access to the mine, and for information relating to it, and to Mr. Brooks, Mr. Ditchburn, and the various officials of the mine for their kind co-operation in the work.





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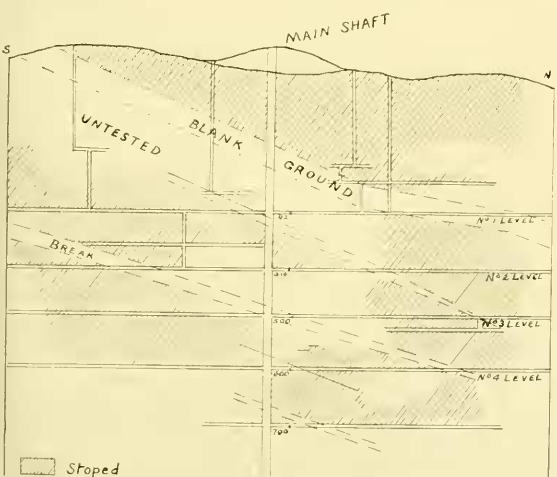
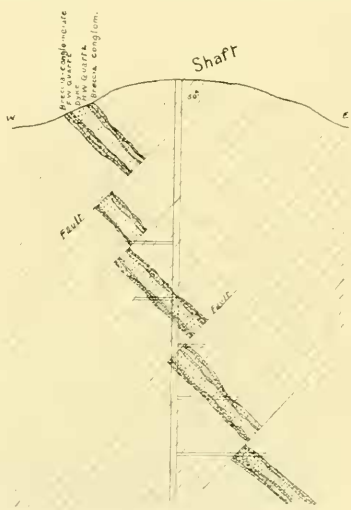


LONGITUDINAL SECTION OF MINE



TRANSVERSE SECTION